

## SPH4U: Relativity Problems

1. **Chasing Light.** What fraction of the speed of light does each of the following speeds  $v$  represent? What is  $v/c$ ?

- a) continental drift, 3 cm/y
- b) 401 highway, 100 km/h
- c) supersonic plane, Mach 2.5 = 3100 km/h
- d) earth orbiting the sun, 30 km/s

2. **Deducing a Speed.** A pulse of protons arrives at detector D, where you are standing. Prior to this, the pulse passed through detector C, which lies 60 m upstream. Detector C sent a light signal in your direction at the same instant that the pulse passed through it. At detector D you receive the light signal and the proton pulse separated by a time of 2 ns. What is the speed of the proton pulse?

3. **Travelling to Vega.** A certain physics student takes off from Earth and travels towards the star Vega, which is 26 ly distant from Earth. Earth and Vega are relatively at rest and the student moves at  $0.99c$  as seen from Earth. How much time will have elapsed on Earth (a) when the student reaches Vega and (b) when Earth receives a radio signal reporting that the student has arrived? (c) How much will she age during her outward trip?

4. **Fast-Moving Muons.** The half-life of stationary muons is 1.6 microseconds. Cosmic rays colliding with atoms in the upper atmosphere of the earth create muons. The mean lifetime of high-speed muons in one such burst was measured to be 16 microseconds. (a) Find the speed of these muons relative to the earth. (b) At this speed, how far will the muons move in one half-life? (c) How far would this pulse move if there was no relativistic time dilation?

5. **Lightbulb Radiating Mass.** How much mass does a 100 W lightbulb dissipate when it burns for one full year?

6. **Electron Shrinks Distance.** An evacuated tube at rest in a laboratory has a length 3.00 m. An electron is moving at speed  $v = 0.999\,987c$  in the laboratory along the tube. What is the length of the tube as measured in the frame of the electron?

7. **Traveling to the Galactic Centre.** Can a person, in principle, travel from the earth to the galactic centre, which is 23 000 ly distant, in one lifetime? What constant speed with respect to the galaxy is required to make the trip in 30 y of the traveler's lifetime?

Answers:

- 1. a)  $3.16 \times 10^{-18}$ , b)  $9.26 \times 10^{-8}$ , c)  $2.87 \times 10^{-6}$ , d)  $10^{-4}$
- 2.  $0.990c$  or  $2.97 \times 10^8$  m/s
- 3. a) 26.3 y, b) 52.3 y, c) 3.71 y
- 4. a)  $0.995c$ , b)  $4.8 \times 10^3$  m, c) 480 m
- 5.  $3.51 \times 10^{-8}$  kg/y
- 6. 1.5 cm
- 7.  $v = 0.999\,999\,15c$